

# MYRRHA

## Technology Development for the realisation of ADS in EU: Current Status & Prospects for Realisation

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On behalf of the MYRRHA & FP7 CDT Teams

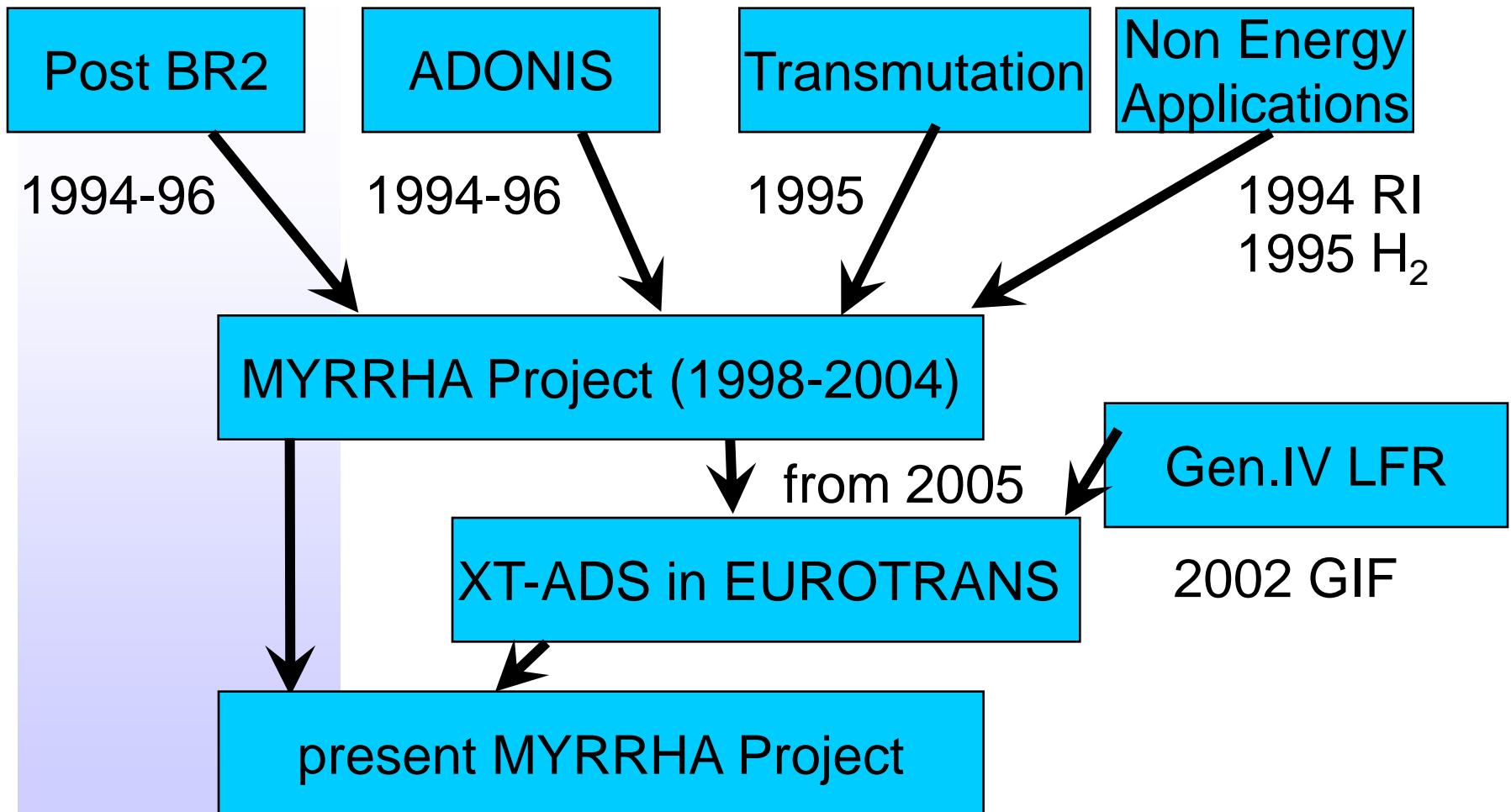
# Outline

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- Genesis of the idea of ADS at SCK•CEN
- International reviewing
- Design evolution
- Components of present design
- Towards implementation
- Conclusions

# Genesis of MYRRHA project and its evolution



# MYRRHA international reviewing



- 2001: International Strategic Guidance Committee
- 2002: International Technical Guidance Committee
- 2003: Review by Russian Lead Reactor Technology Experts (ISTC#2552p project)
- 2005: Conclusions of the European Commission FP5 Project PDS-XADS (2001-2004)
- 2006: European Commission FP6 Project **EUROTRANS** (2005-2009): Conclusions of Review and Justification of the main options of XT-ADS starting from MYRRHA
- 2007: International Assessment Meeting of the Advanced Nuclear Systems Institute
- 2008: European Commission FP7 Project Central Design Team (CDT) at Mol for MYRRHA detailed design
- **2009: OECD/NEA MIRT (MYRRHA International Review Team) on request of Belgian Gov. in view of decision for funding**

# MYRRHA design evolution

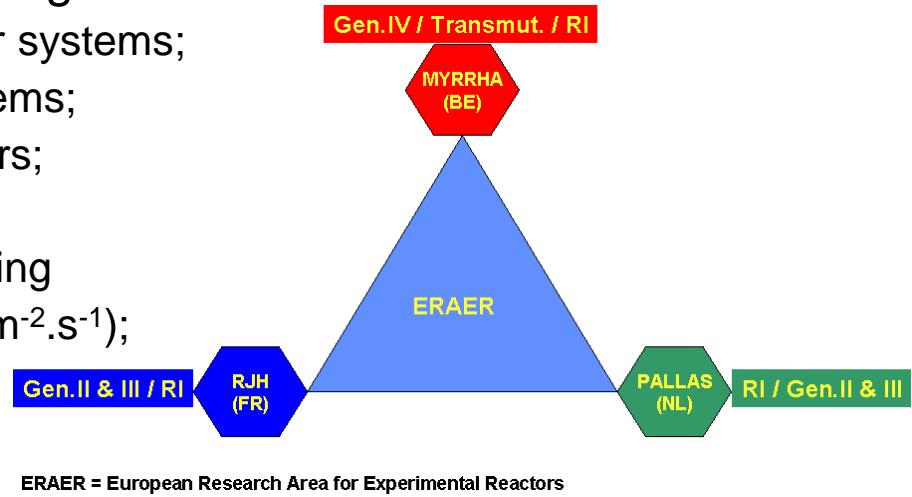


Draft 2 2005	XT-ADS 2006-2009	XT-ADS-HF end 2009	FASTEF 2012
LINAC 350MeV	LINAC 600MeV	LINAC 600MeV	Subcritical design optimisation and critical operation
High power density core ' <u>Safety</u> <u>'ULOF'</u> '	Low power density core	Low power density core	
Low core power 52MW	Low core power 57MW	High core power 85MW	
Neutron flux $10^{15}n/cm^2s$ (>0.75MeV)	Neutron flux $7.10^{14}n/cm^2s$ (>0.75MeV)	Neutron flux $10^{15}n/cm^2s$ (>0.75MeV)	

# MYRRHA/FASTEFL objectives



- To be operated as a flexible fast spectrum irradiation facility working in subcritical **and critical mode** allowing for:
  - fuel developments for innovative reactor systems;
  - material developments for GEN IV systems;
  - material developments for fusion reactors;
  - commercial services
  - **efficient transmutation of MA** requesting high fast flux intensity ( $\Phi_{>0.75\text{MeV}} = 10^{15} \text{n.cm}^{-2}.\text{s}^{-1}$ );



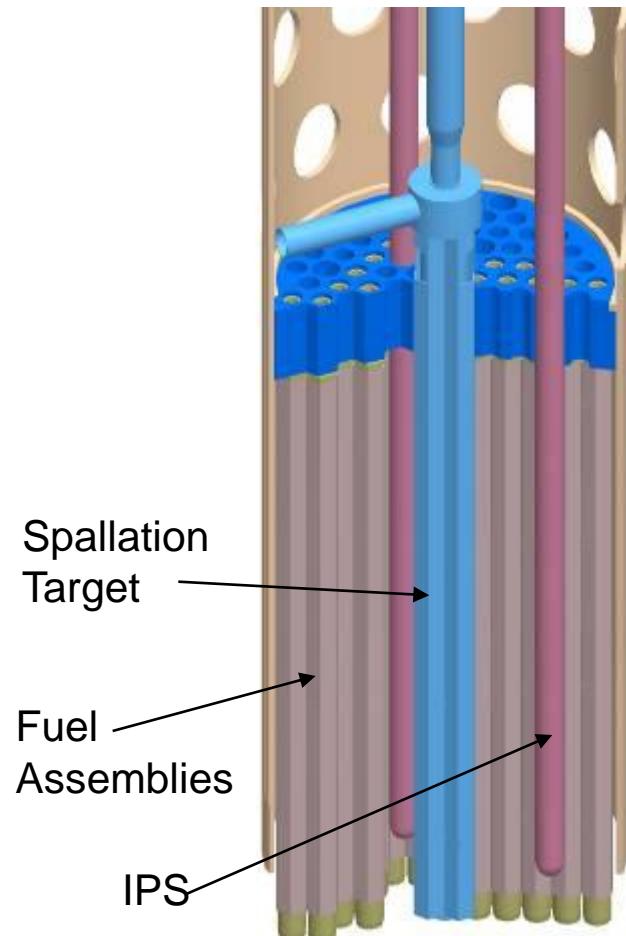
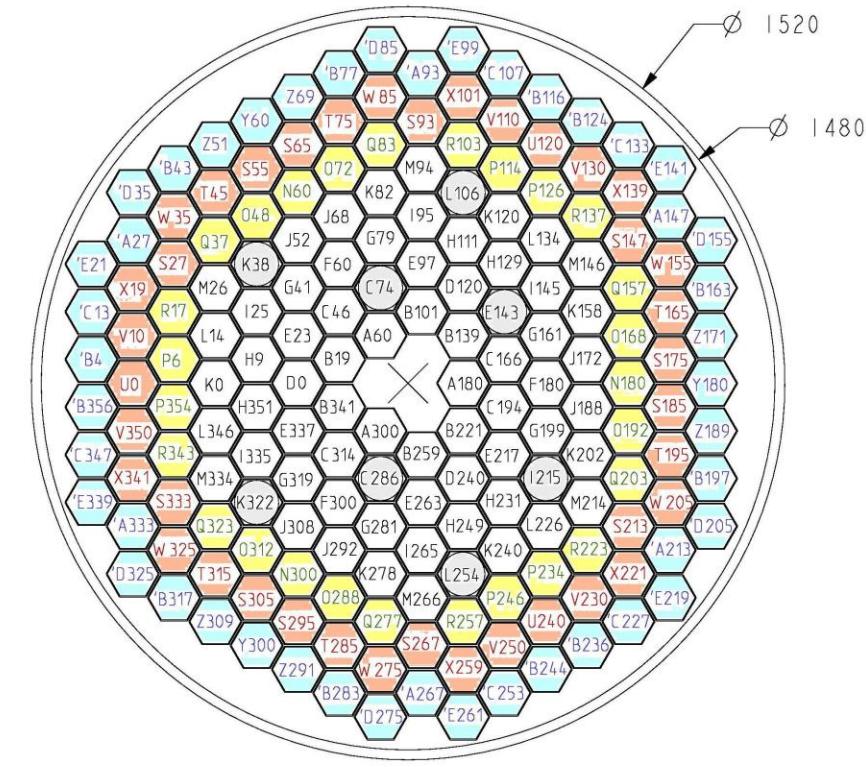
- To demonstrate the **ADS full concept** by coupling the three components (accelerator, spallation target and sub-critical reactor) at reasonable power level scalable to an industrial demonstrator;
- To contribute to the demonstration of LBE technology and to demonstrate the **critical mode operation** of a heavy liquid metal cooled reactor as an alternative technology to SFR

# Core performances

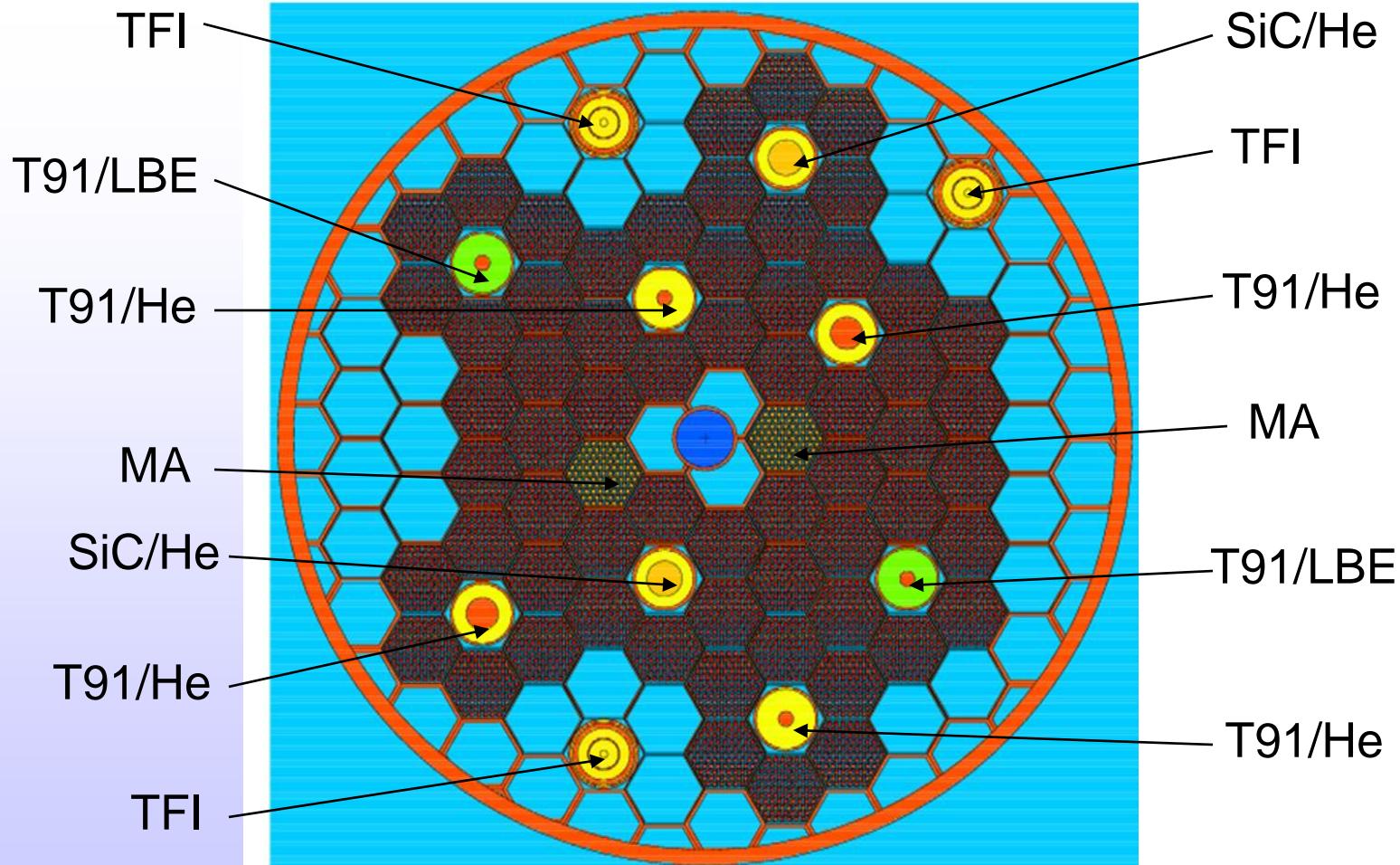


Parameter	(unit)	XT-ADS HF
Core power	MW <sub>th</sub>	85
Active core average power density	W/cm <sup>3</sup>	246
Fast flux above 0.75 MeV	n/cm <sup>2</sup> .s	10 <sup>15</sup>
Inlet temperature	°C	270
Coolant ΔT	°C	130
LBE Velocity (fuel rod)	m/s	1.72
LBE Velocity (spacer-grid)	m/s	2.50
Temperature at clad surface	°C	496
Maximum linear power	W/cm	372
Pressure drop	mb	1066

- $k_{\text{eff}} \approx 0.95$
  - 30-35 % MOX fuel
  - Core height 60 cm x Ø 100 cm
  - 70 MWth



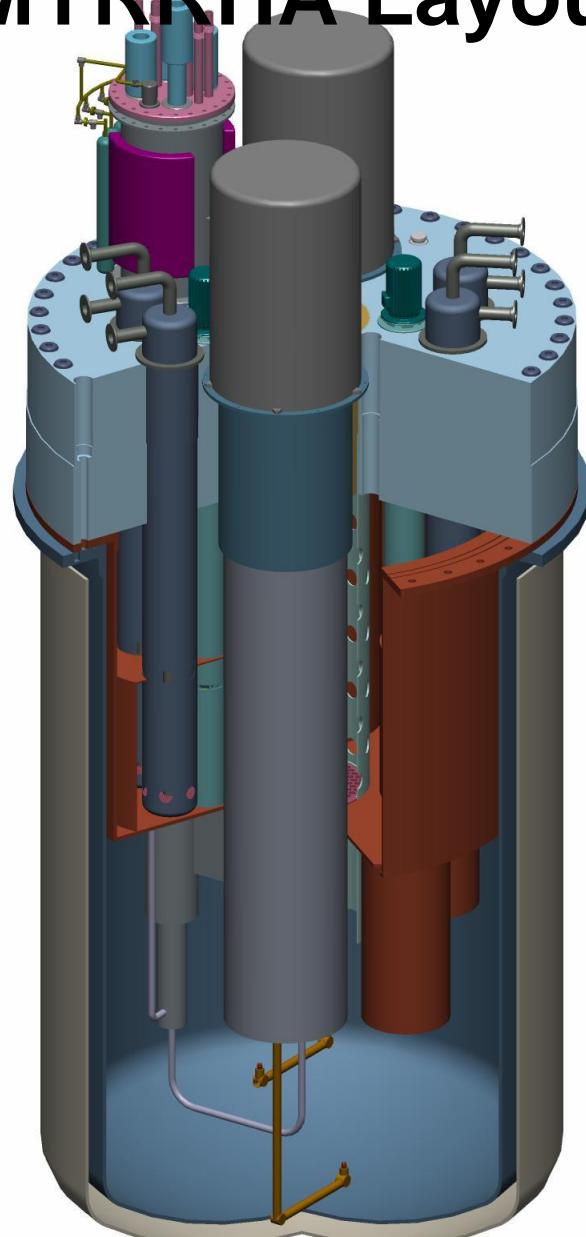
# Flexible Irradiation facility



# MYRRHA Layout



- Inner vessel
- Cover
- Core structure
- Spallation loop
- Heat exchangers
- Pumps
- Diaphragm
- Fuel storage
- Fuel manipulators
- Guard vessel



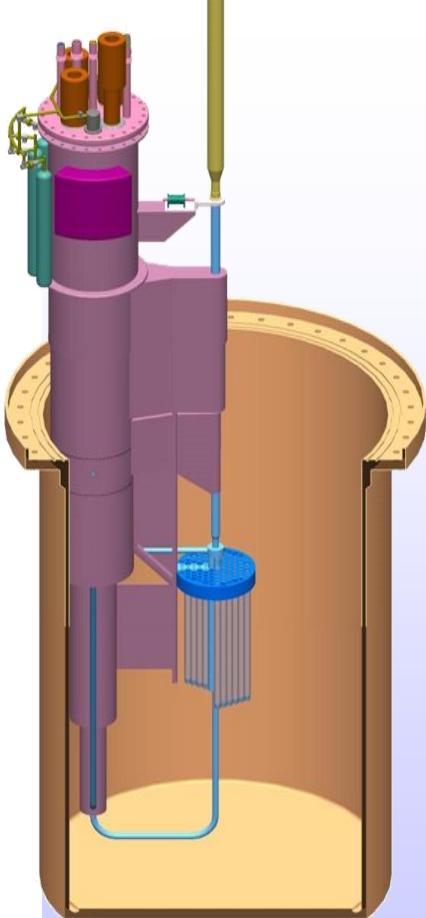
# Confirmation of design choices



Confirmations of design choices within FP6 IP-EUROTRANS by European Partners (2006-2009)  
(AREVA, ANSALDO, EA, FZK, CEA, CNRS and others)

- Core specifications
- General specifications of primary system
- In-vessel fuel handling from beneath the core

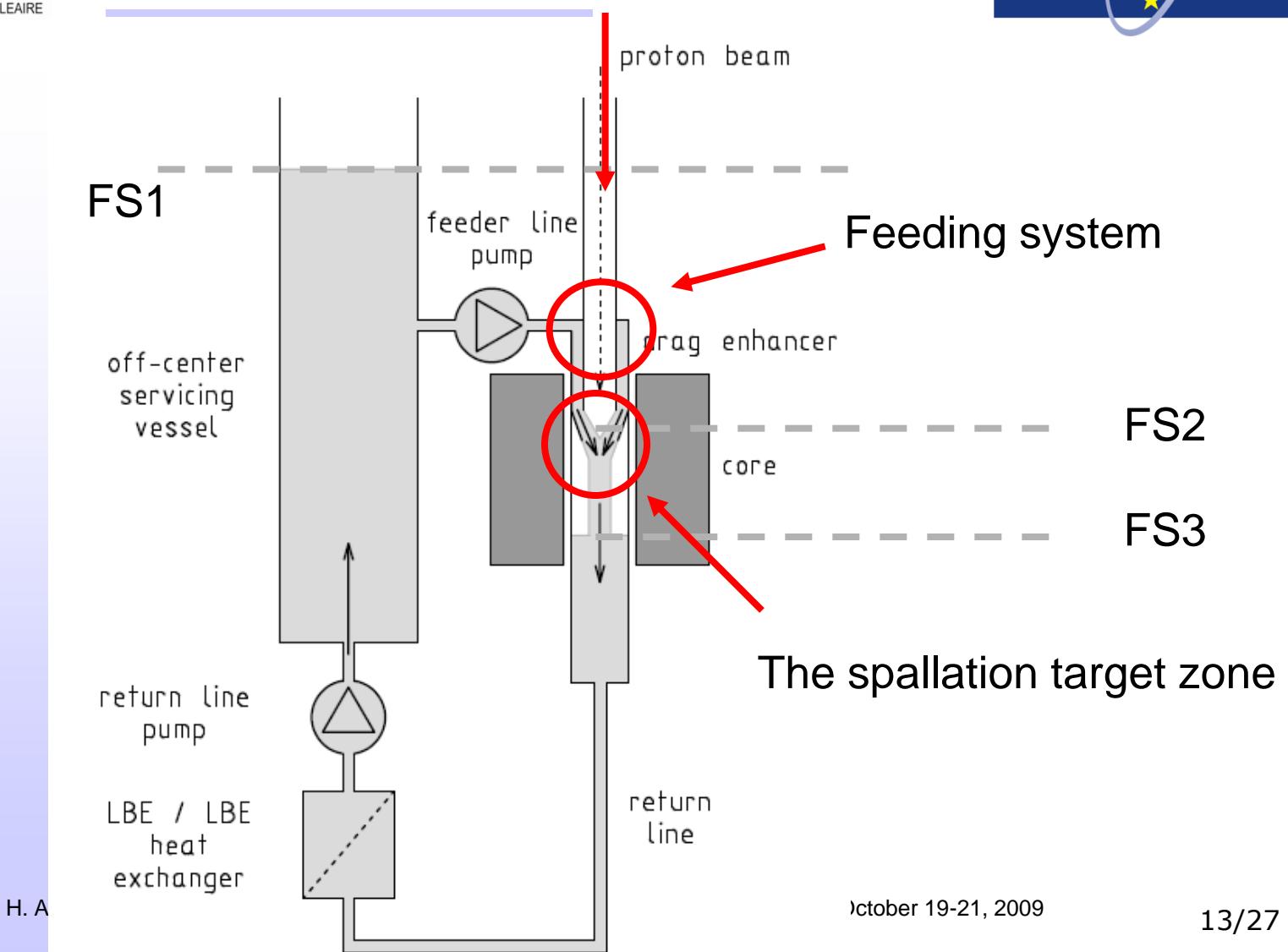
# Spallation target & loop design



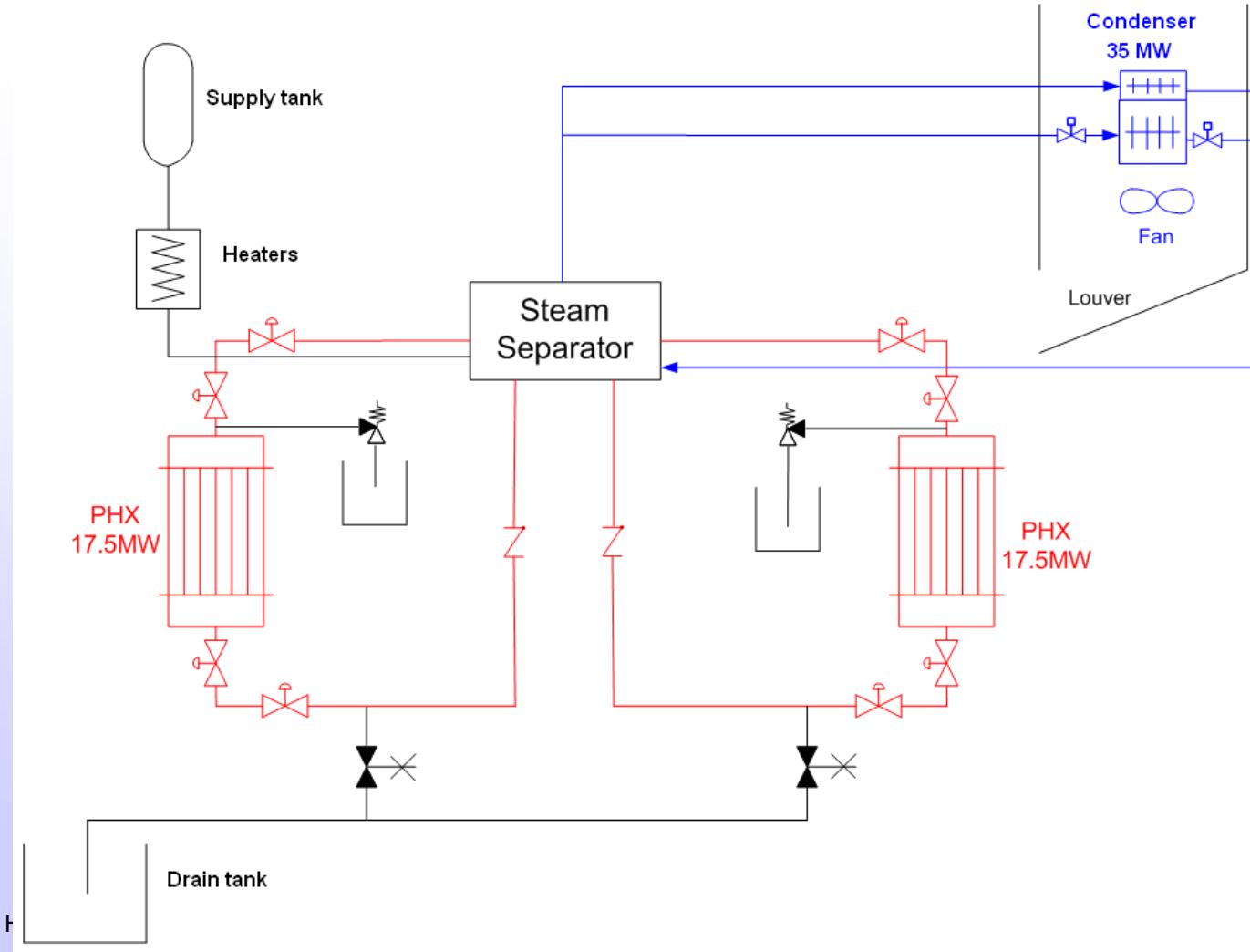
- accept megawatt proton beam
  - 600 MeV, 2.5-3 mA → ~1-1.2 MW heat
- fit into central hole in core (3 fuel hexagons removed)
  - compact target
  - off-axis geometry
- match MYRRHA purpose as experimental irradiation machine
  - flexible remote handling
- survive (lifetime)

→ Windowless design and off-centre spallation loop

# Windowless Target Flow



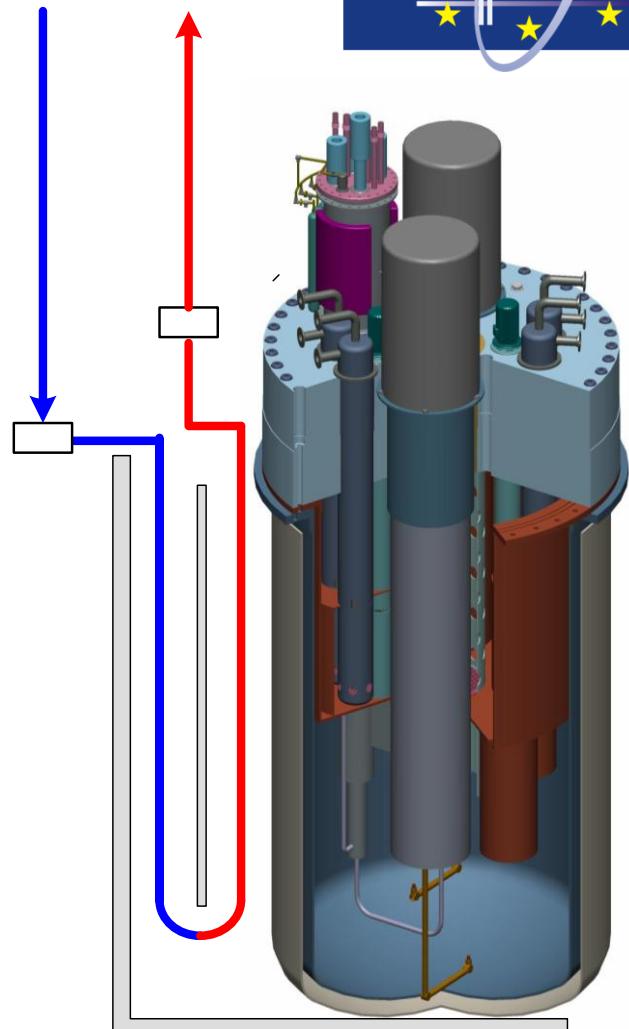
# Passive secondary and tertiary cooling system



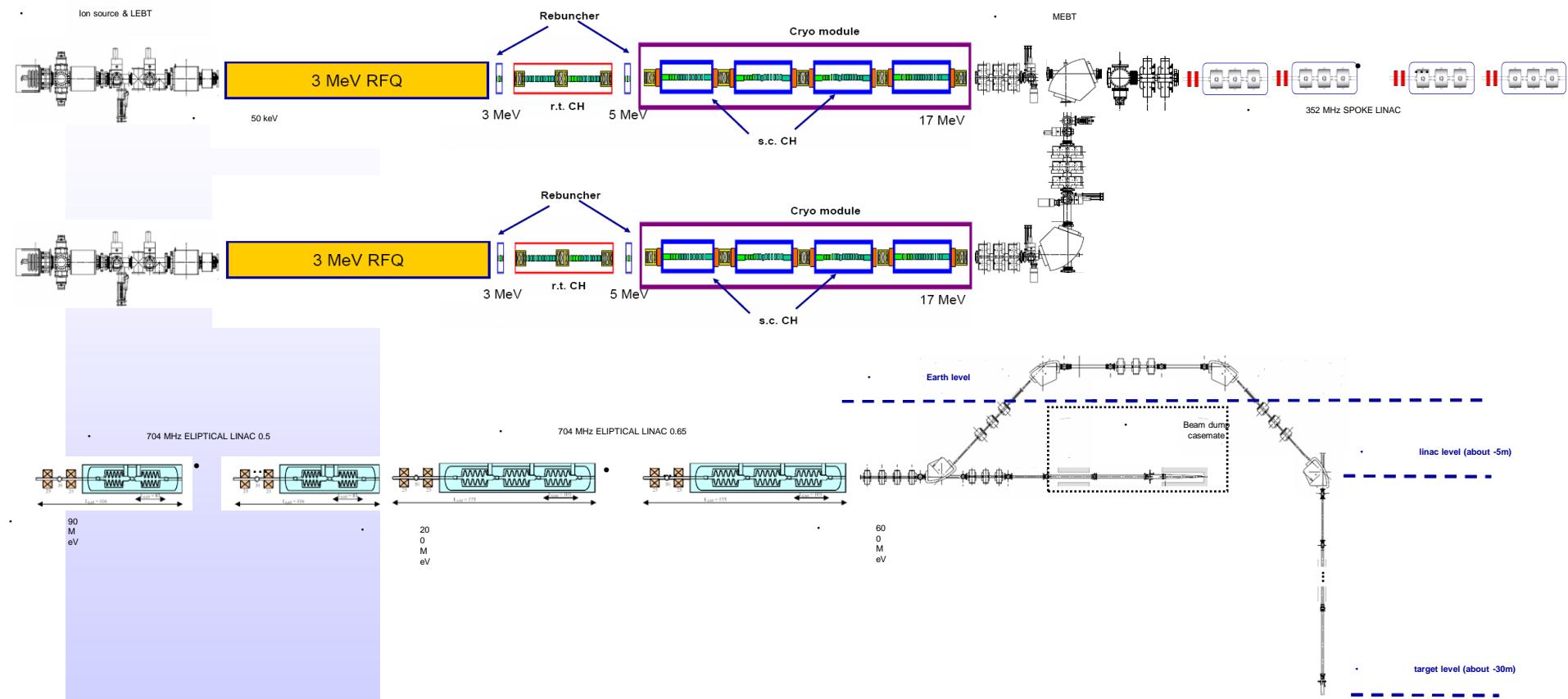
# Decay heat removal system



- Decay heat removal (DHR) through secondary loops
  - 2 independent loops
  - redundancy (each loop has 100% capability – min. sized for 3% continuous power)
  - passive operation (natural convection in primary, secondary and tertiary loop)
- Ultimate DHR through RVCS (natural convection)



# LINAC Layout



# Safety criteria



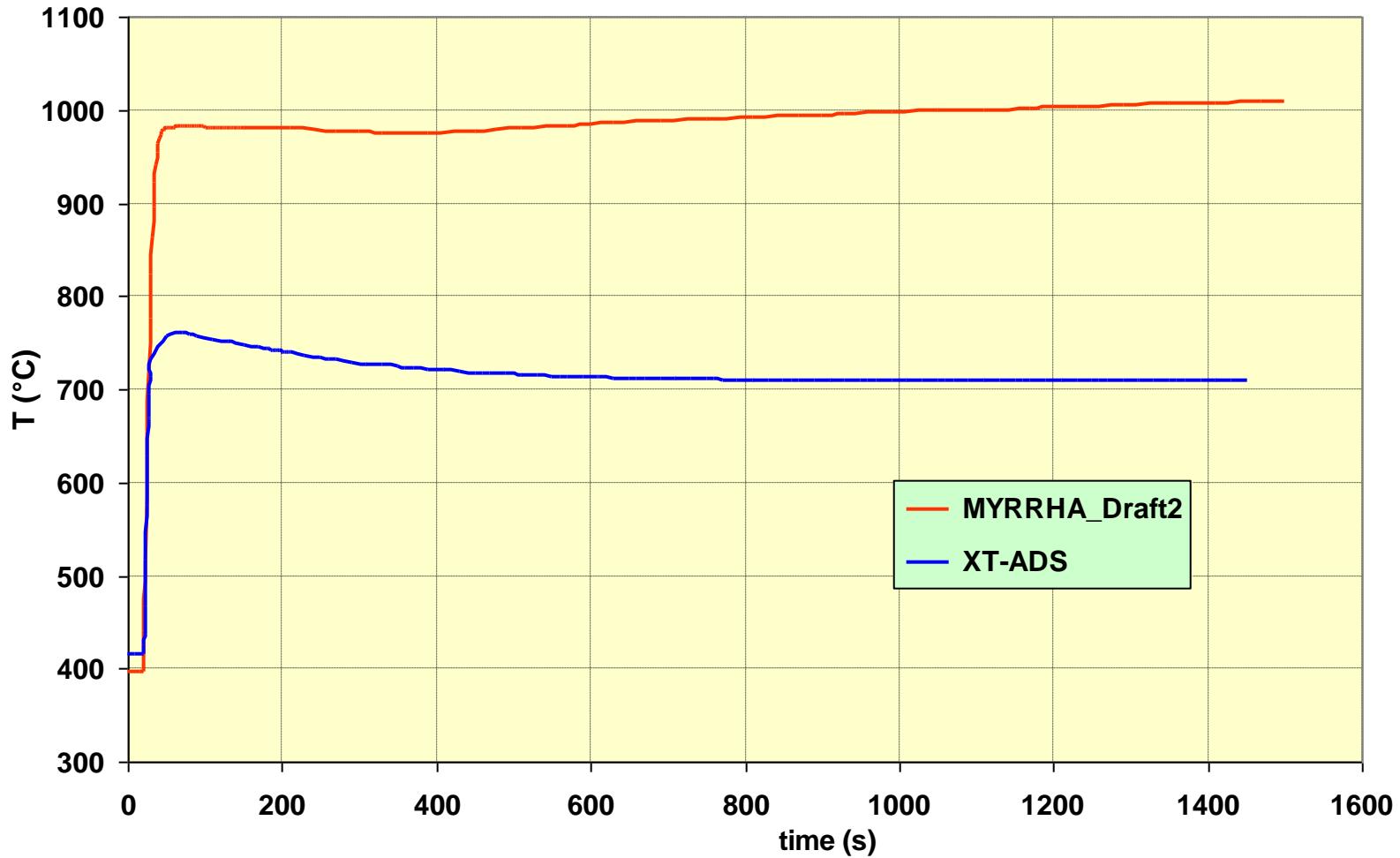
- **Fuel (MOX): no melting**
  - $T < 2707^\circ \text{ C}$  for fresh fuel
  - $T < 2673^\circ \text{ C}$  for 100 MWd/kg burnup
- **Cladding (T91):**
  - steady state  
**embrittlement**  $\Leftarrow 200\text{-}300^\circ \text{ C} \leq T \leq 500\text{-}550^\circ \text{ C} \Rightarrow **corrosion**$
  - transient  
no creep rupture  $\Rightarrow T < 800^\circ \text{ C}$  for max. 30 min
- **Coolant (LBE): no freezing  $\Rightarrow T > 138^\circ \text{ C}$**

# Safety improvements in XT-ADS

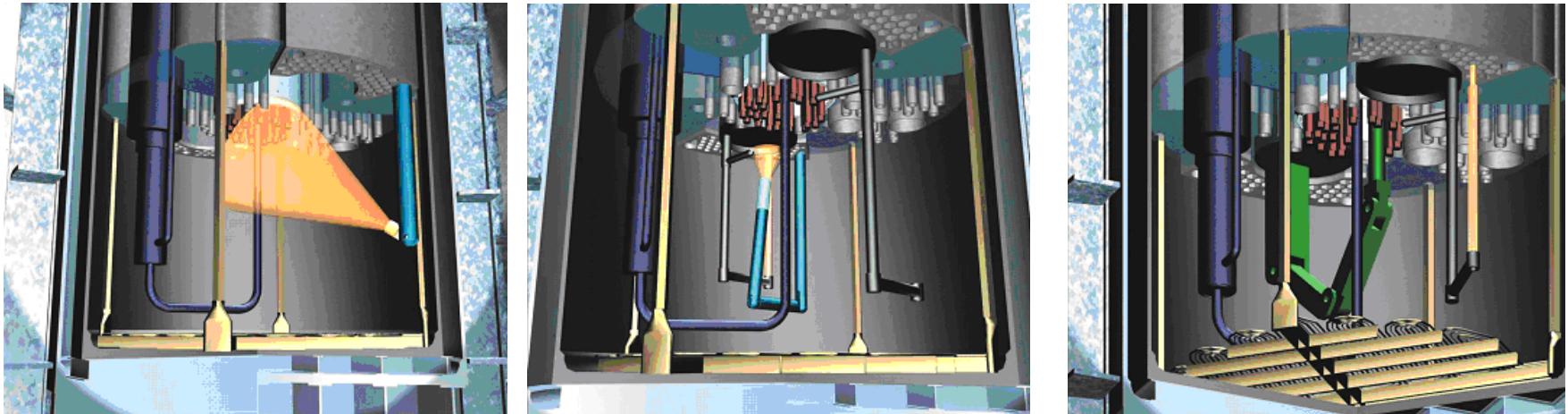


- Unprotected events addressed by improvement of natural convection
  - core hydraulic resistance reduced
  - level difference between core and PHX increased ( $1,2\text{ m} \rightarrow 2\text{ m}$ )
- Boiling water HX instead of pressurized water HX to mitigate tube rupture consequences
- Ultimate DHR by RVCS system

# Maximum clad temperature during a ULOF

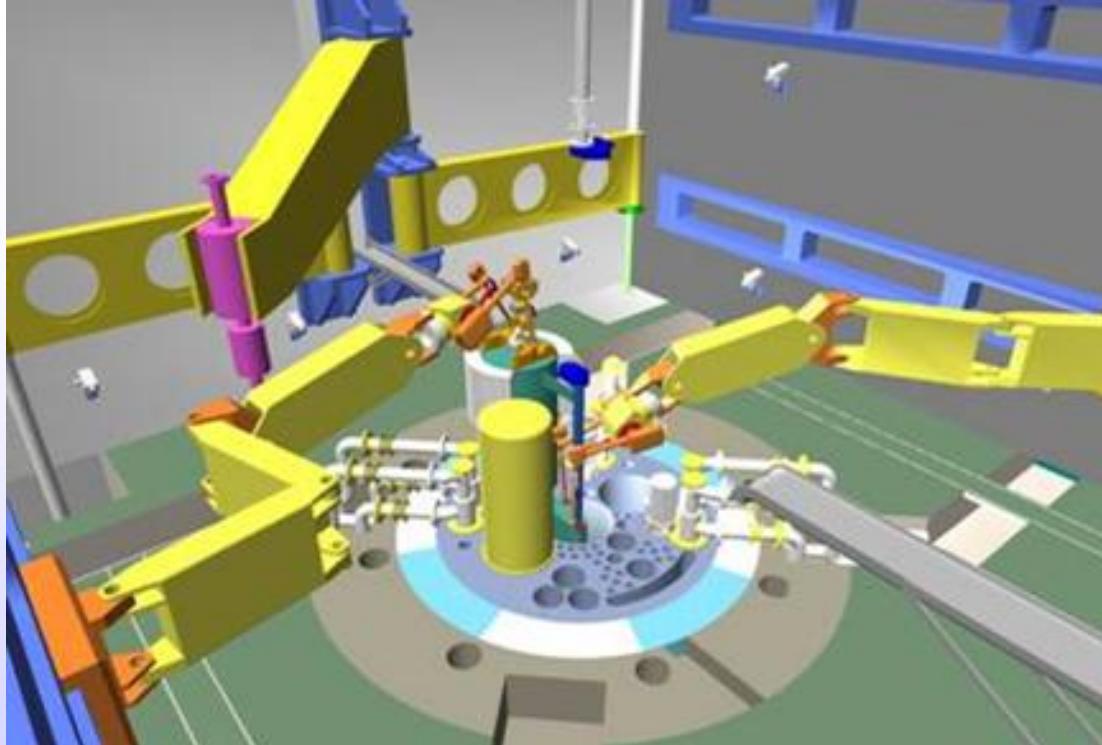


# In Service Inspection with US & In-vessel Repair



O.T.L. concludes positive on the feasibility

# Ex-vessel remote handling



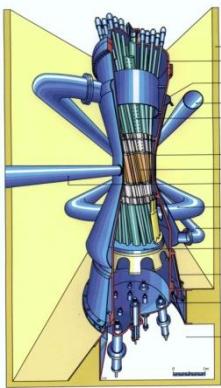
O.T.L. concludes positive on the feasibility

# Main topics for design optimisation & detailing (2009 – 2011)

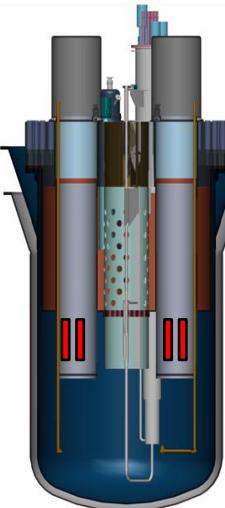
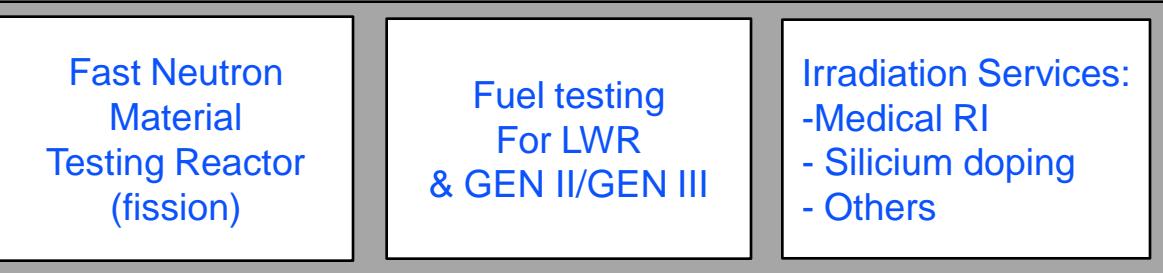


- Nuclear island
  - Reactor cover/plug & containment
  - In-vessel fuel storage
  - In vessel fuel manipulators
  - US camera visualisation
  - Inspection & repair manipulators
- Fuel procurement & qualification
- Balance of plant

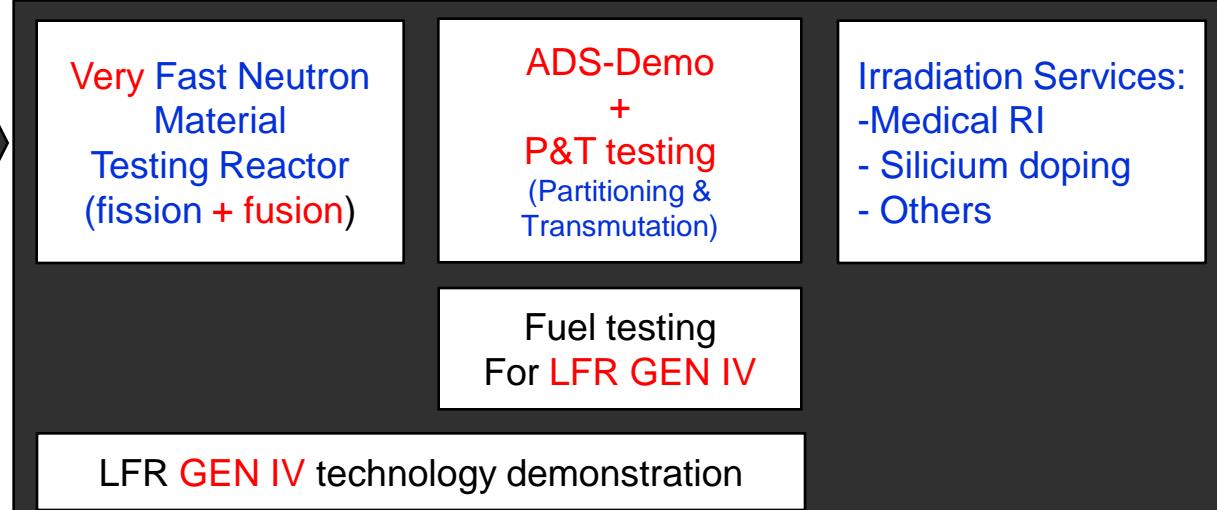
# Why MYRRHA at SCK•CEN ?



1962  
BR2



2020  
MYRRHA



# Project schedule



**2009-2011**

Detailed  
Engineering  
Design

**2012-2013**

Techn.specs  
**Call for  
Tenders  
& Awards**

**2014-2016**

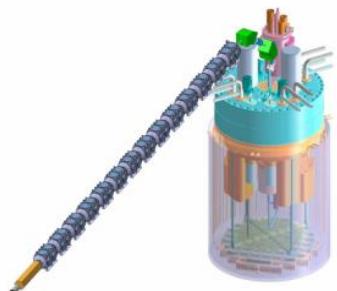
Construction  
of components  
& Civil Works

**2017**

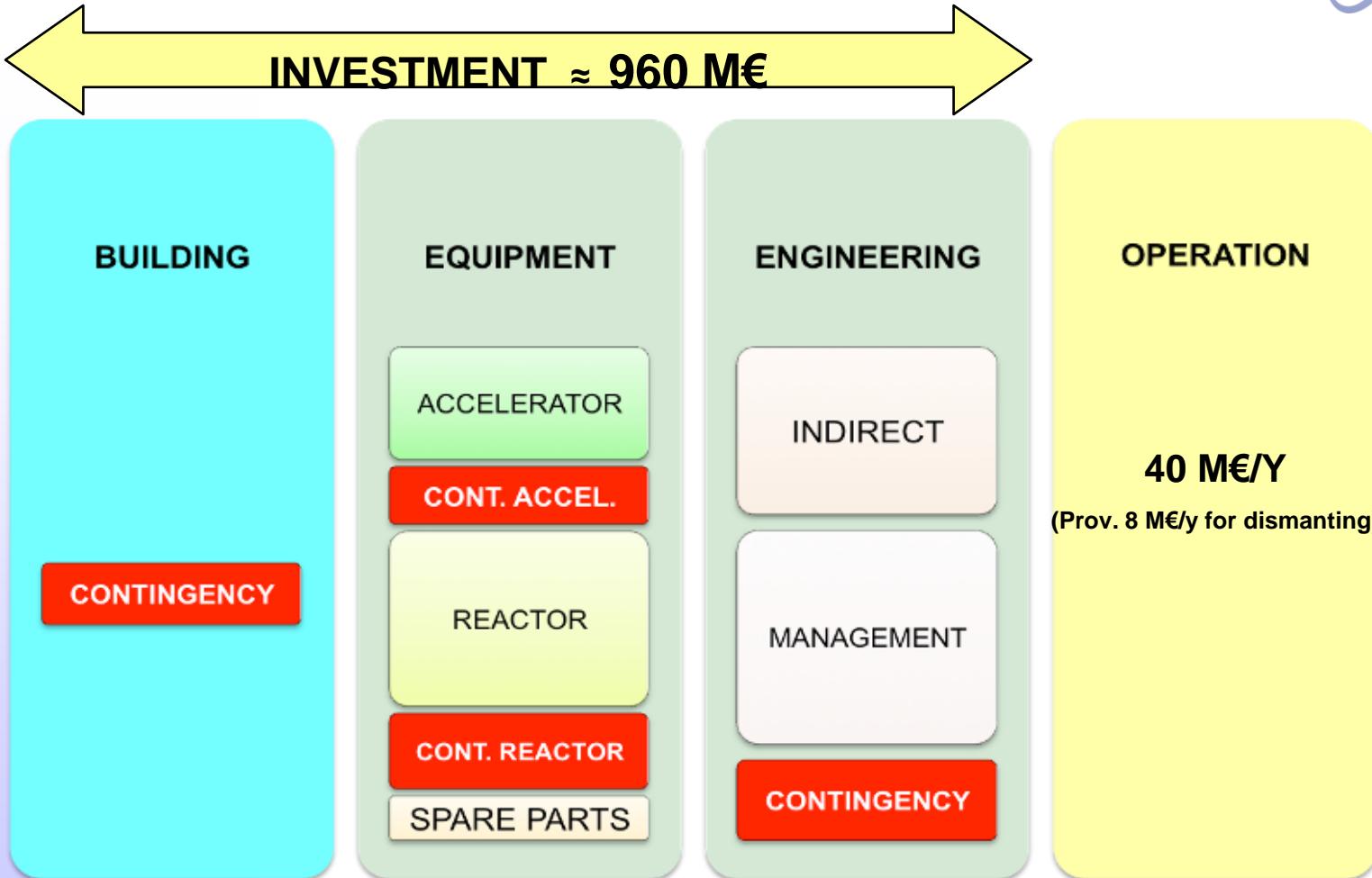
Components  
assembly  
on site

**2018-2019**

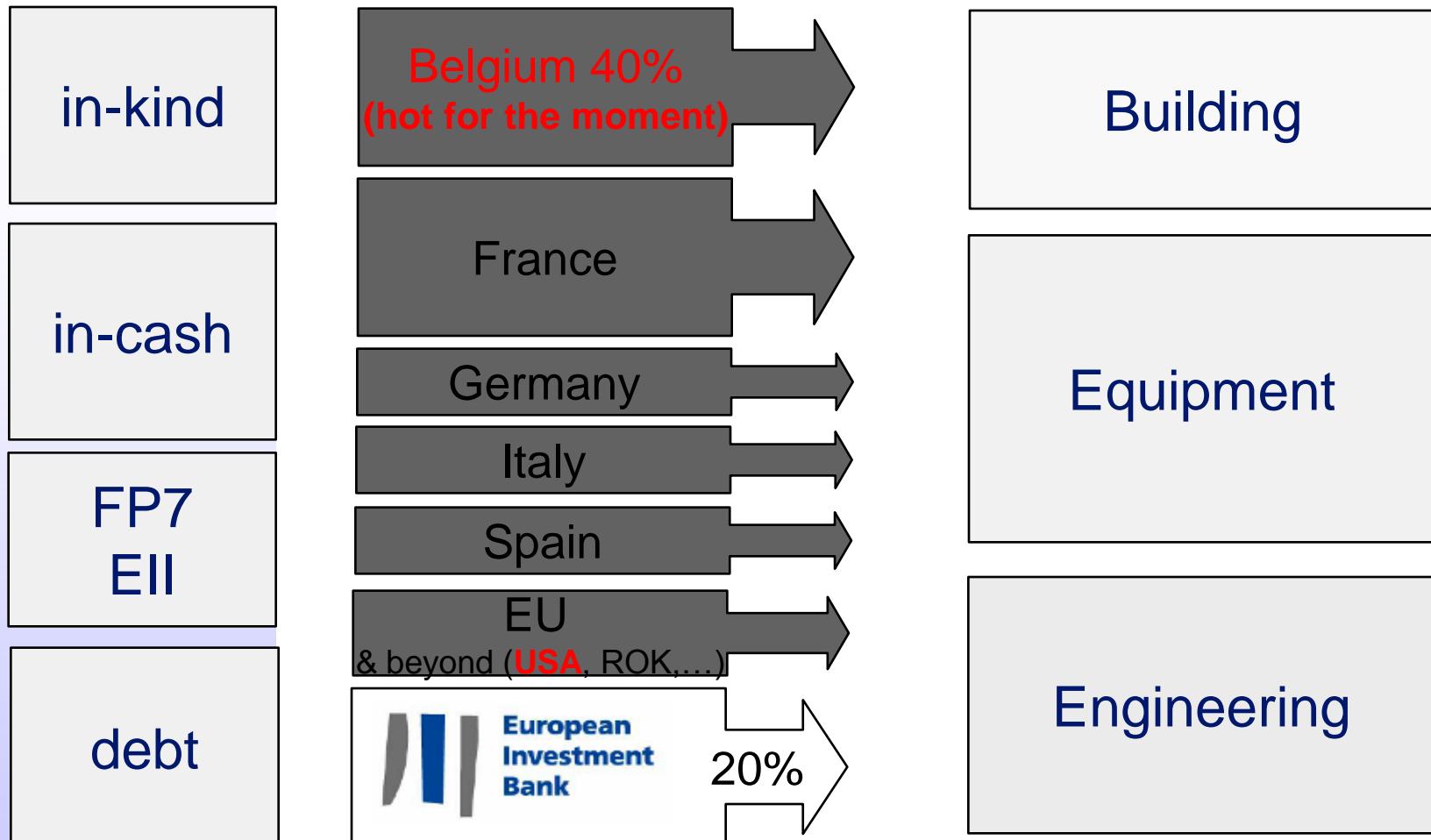
Commissioning



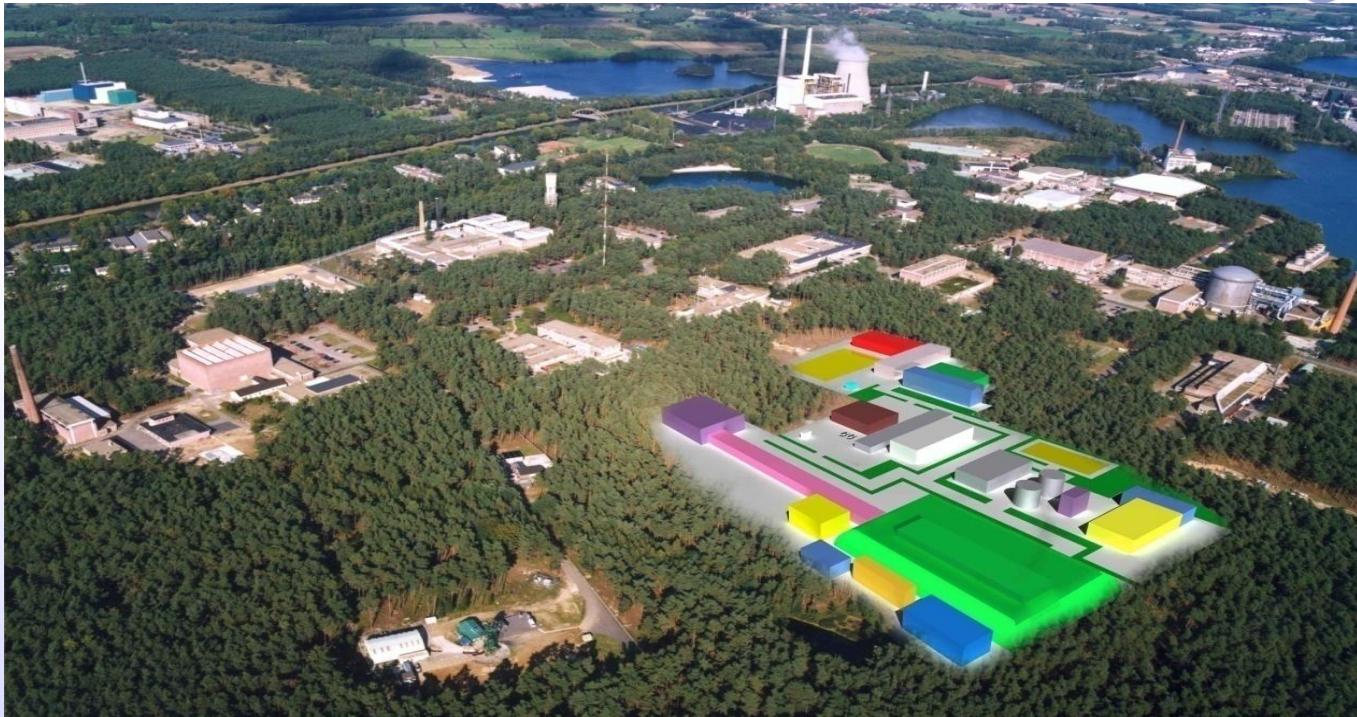
# MYRRHA: Investment budget (in €2009)



# MYRRHA: Source of funds



# Conclusion



with MYRRHA we will reach  
**Science towards Sustainability**